appears to be real, because this region (facing Neptune) was the part of Triton seen best by the Voyager 2 spacecraft. This cratering pattern is too asymmetric to be accounted for by comets or other objects that orbit the sun. Required, rather, are objects in prograde orbit around Neptune. Such objects would strike Triton mostly head-on, and the resulting craters would be confined mostly to the leading hemisphere. The origin of the implied swarm of prograde, Neptune-orbiting debris is an open question. The alternative explanation is that Triton has been capriciously resurfaced so as to appear, from the one viewpoint of the Voyager 2, as if it had run face-first into a swarm of debris.

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EXOBIOLOGY

## A Greenhouse Co-Laboratory

Brad Bebout, Richard Keller

The Ames Microbial Ecology/Biogeochemistry Research Lab, in combination with the ScienceDesk team, has made significant progress in realizing a greenhouse "co-laboratory," which will be shared by members of the NASA Astrobiology Institute's Early Microbial Ecosystems Research Group (EMERG). (See figure 1.) The greenhouse facility is being used to maintain and perform manipulations of field-collected microbial mats. Microbial mats, extant representatives of Earth's earliest ecosystems, are highly dynamic communities of microorganisms that exhibit extremely high rates of metabolic processes. Maintaining the structure and function of these communities outside the natural environment is, therefore, a challenge. Using the greenhouse constructed on the roof of Building N239, mats that resemble naturally occurring communities have been maintained over a year after field collection. In FY00 it was determined that the greenhouse-maintained mats sustain natural rates of biogeochemical processes. This facility, therefore, is useful to support continued measurements of the rates and conditions under which various trace-gases are emitted and/or consumed by microbial mats and stromatolites. The greenhouse mats will be used to investigate the effects of early Earth environmental conditions on the rates of trace-gas production and consumption in the microbial mats, a period of Earth's history no longer available to us for direct measurement. These measurements are also relevant to the search for life on extrasolar planets, where the most promising search strategy involves the detection of possibly biogenic gases using infrared spectrometry. Space-based interferometers, such as the Terrestrial Planet Finder, should be able to resolve the spectra of several biologically important trace gases in the atmospheres of extrasolar planets, possibly within 10–15 years.

The greenhouse represents a unique facility and a unique resource to be shared among EMERG team members. The scientific objectives of the team require multiple collaborators to conduct and analyze measurements of mat parameters on a frequent basis over many weeks. However, pragmatics and funding constraints inhibit the productivity of the distributed team and prevent full utilization of the greenhouse. The construction of a

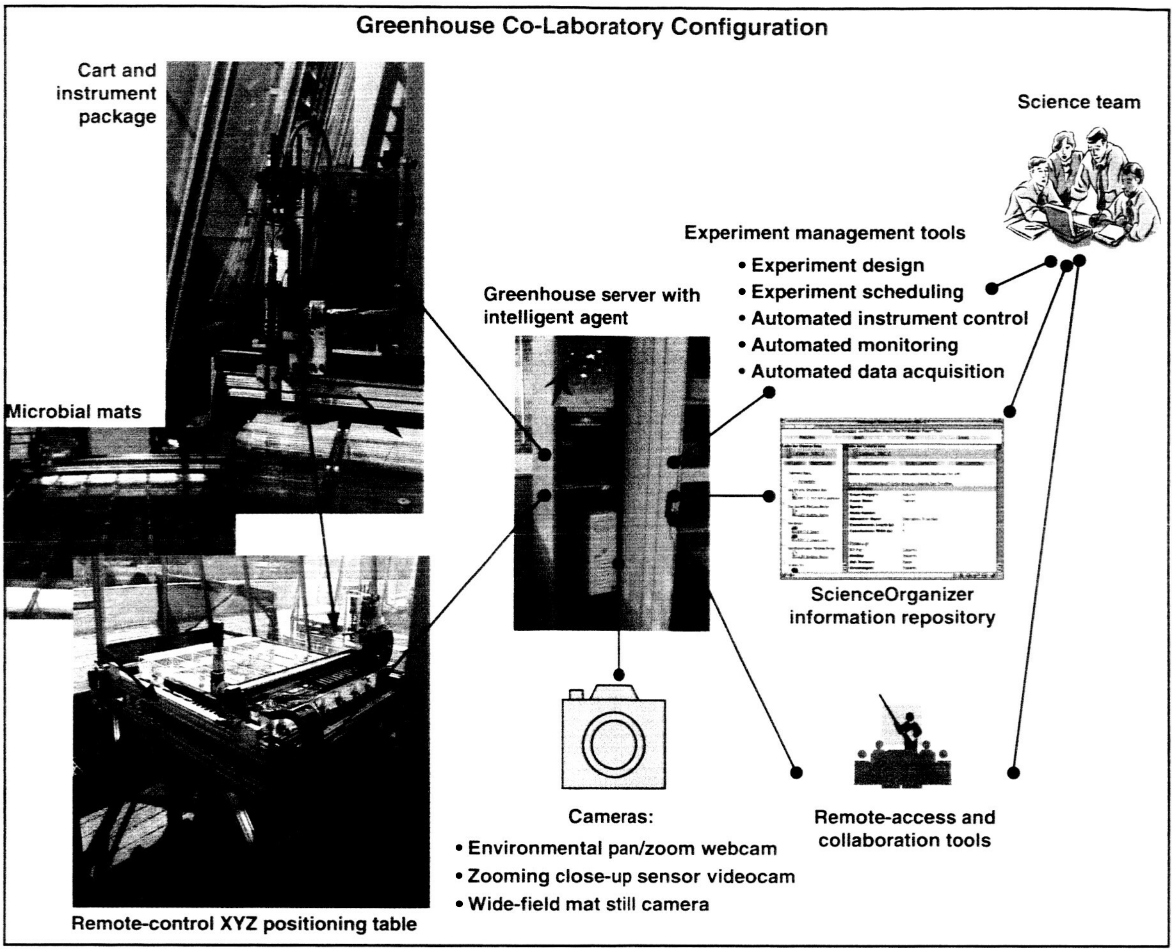


*Fig. 1. Diagrammatic representation of the greenhouse co-laboratory with photographs of the hardware already in place.*

co-laboratory—in which human scientists and intelligent software agents work together to perform experiments—will alleviate demanding proximity and time requirements that affect productivity. Rather than placing the burden solely on local team members, a co-laboratory will enable an entire distributed investigator team to share responsibility for experimentation and data collection.

This motivation has led to construction of a co-laboratory designed to enable the geographically distributed group of EMERG scientists to plan greenhouse experiments, operate scientific equipment, take experimental measurements, share results, and collaborate in real time with remote colleagues. Intelligent software agents will assist in the experimentation process, controlling the hardware, recording results, and interacting with the scientists via e-mail. As part of the initial hardware development for the co-laboratory, an X,Y,Z positioning table that is capable of automatically positioning sophisticated instruments at any location in the mats has been constructed. The instrument package currently includes microelectrodes, a light sensor, a chlorophyll fluorometer, a surface-detection device, and a fiber-optic spectrometer. The positioning system and the instrumentation package are viewable over the Internet (http://greenhouse.arc.nasa.gov) via a webcam hooked up to a computer located in the greenhouse. Next implementation steps involve controlling the positioning table and equipment remotely over the Internet.

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## CHEMIN: A Mineralogical Instrument for Mars Exploration

David F. Blake

The identification of the types of rocks on Mars that may harbor evidence of present or past life (that is, biomarkers) will require *in situ* mineralogical analysis. In order to establish the conditions under which a rock formed, the identity of each mineral present and its amount must be determined. In terrestrial laboratories, x-ray diffraction and x-ray fluorescence (XRD/XRF) are the techniques of choice for such characterizations.

Recent progress in x-ray technology allows the consideration of simultaneous x-ray diffraction (XRD: mineralogic analysis) and high-precision x-ray fluorescence (XRF: chemical analysis) in systems scaled down in size and power to the point at which they can be mounted on landers or small robotic rovers. The CHEMIN XRD/XRF instrument, which simultaneously collects XRD and XRF data, has been proposed in the past for a variety of solar-system missions and is presently proposed for three separate Mars scout missions, including a precision lander, a penetrator, and a lander equipped with a drill.

NASA was awarded a patent in 1996 (U.S. Patent No. 5,491,738) for the CHEMIN concept. The instrument received a commercial "R&D 100 award" as one of the top 100 innovative technologies of 1998. A SBIR (Small Business, Innovative Research) phase II proposal has been awarded to Moxtek, Inc. to build and commercialize a laboratory version of CHEMIN.

CHEMIN is a charged-coupled device (CCD)-based simultaneous XRD/XRF instrument. The device is designed to characterize the elemental composition and mineralogy of small fine-grained or powder samples. The name CHEMIN refers to the combined CHEmical and MINeralogic capabilities of the instrument.

Diffraction and fluorescence data are obtained simultaneously by operating the CCD in single-photon counting mode. Energy discrimination is used to distinguish between diffracted primary beam photons and fluorescence photons. Diffraction data are obtained in transmission mode, and resolution is presently sufficient on the prototype instrument to allow application of the Rietveld refinement method to the diffraction data. X-ray fluorescence data will be obtained for all elements, $4 < Z < 92$.

A diagram of the proposed CHEMIN flight instrument is shown in figure 1. In operation, the carousel of the instrument (which is the only moving part) is rotated to place one of 40 collection grids in a position to receive a soil sample or a sample of drill cuttings from a rock. The carousel is then rotated to place the grid in the analysis position between the x-ray source and the CCD. A combination of carousel rotation and 1- to 2-millimeter motion along the x-axis allows the entire substrate to be sampled sequentially by the x-ray beam. An intelligent systems program determines the location of sample material suitable for analysis and supervises data collection.